APCC – SPC Rountable on the State of the Art of Coconut Processing and Market Prospects of Coconut Products the Pacific Countries

17 - 18 June 2009,Tanoa International Hotel, Nadi, Fiji

EU-Facilitating Agriculture Commodity Trade Project

Secretariat of the Pacific Community

Asian and Pacific Coconut Community

Coconut Industry Development Authority

Technology Updates on Filtered Crude Coconut Oil (FCCNO) as Biofuel

Gilles Vaïtilingom

Filtered Crude Coconut Oil as Biofuel

- Vegetable oil as Fuel
- Technology Updates
- Quality requirement of FCCNO as Biofuel for diesel engines
- FCCNO in the Pacific: examples

HISTORY OF VEGETABLE OILS AS FUEL

SINCE NEOLITHIC PERIOD : 9000 before J.C.

BUT: APARITION OF PETROL LAMPS IN 1853

HISTORY OF VEGETABLE OILS AS FUEL

Rudolf DIESEL (1858 – 1913)

1900 : test of some vegetable oils in his engine

VEGETABLE OILS AS FUEL

- Characteristics close to diesel oil

LCV coconut oil: 41 MJ/kg
LCV Diesel oil: 44 MJ/kg

Density coconut oil: 0.92
Density Diesel oil: 0.83

- History:

  - Mr. Diesel himself in 1900
  - World War II
  - Banned from research in the 50'
  - interest renewed at the end of 70'
  - But: last International Congress in 1982.

COCONUT OIL AS FUEL
Why so few applications ?

- higher cost than diesel ☞ case of most renewable

  But new position with > USD 70/barrel

- too different to respect fuel standards

  New standards on the way: soon in Fiji

- Coconut Oil ! Not to be compared to a cheap, common and stinking product

  New consideration → USD 70 for 159 liters

STOP **Coconut oil Biofuel is not Diesel Fuel and must be used in adapted engines only!**

VEGETALES OILS AS FUEL FOR DIESEL ENGINES

Piston after 200 hrs. with diesel fuel at idle speed no load

Piston after 21 hrs. with sunflower oil at idle speed no load

WHY ?

CONSEQUENCES (1)

CARBON DEPOSIT

Figure 10 - encrassement typique dû aux huiles végétales (piston de moteur à injection directe, 10 heures de ralenti à vide, huile de tournesol raffinée)

MECHANICAL DAMAGES

Injection pumps, rings, cylinder,…

CONSEQUENCES (2)

CARBON DEPOSITS

nozzle, valves,…

Technology Updates

Vegetable oils:

1. In standard Diesel engines by either:

- **adapting the "fuel" and making *Biodiesel* (esterification with methanol or ethanol).**
- **using pure vegetable oils or mixtures under internal thermal conditions allowing their complete combustion (2- tank systems)**
- **using IDI engines (Indirect injection system)**

2. In specifically designed engines modified to burn vegetable oils at any percentage

Technology Updates

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ESTER OF VEGETABLE OIL

BIODIESEL

In any type of Diesel engines

50 % Diesel - 50 % Methyl Ester (rapeseed oil)

Reims - France

METHYL ESTER OF VEGETABLE OIL

Biodiesel Plant

BIODIESEL

AT SMALL SCALE LEVEL

Coconut oil Biodiesel Small scale Unit. 50 liters / 8 hours.

Tuvalu, TMTI, 2009.

(Green Fuels UK)

2 tonnes/day Biodiesel Unit

Cameroon, 2008.

(Ageratec Sweden)

Source : Cirad Vaitilingom

Technology Updates

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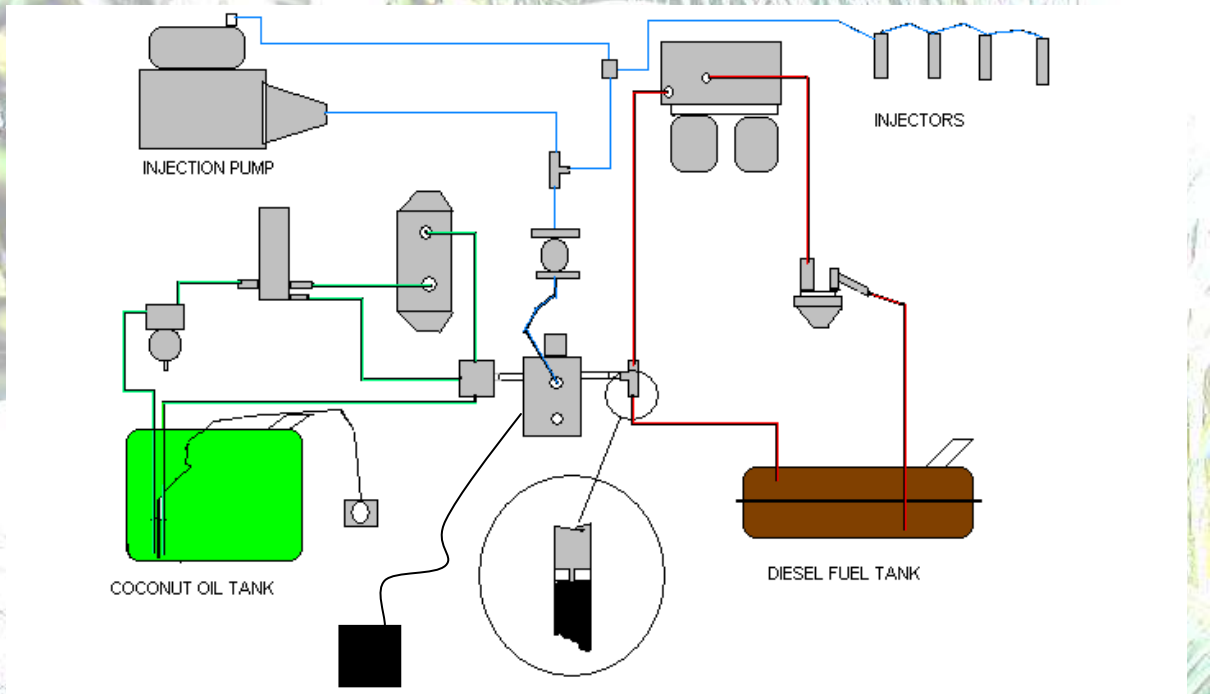
DIESEL DIRECT INJECTION CRUDE PALM OIL

SYSTEM OF DOUBLE CIRCUIT or 2 TANK SYSTEM

Genset Cummins 60 KVA (Brazil, 2009)



Control module

Running on Diesel Fuel from 0 to 30 KVA (load < 50 %)

Running on pure Palm Oil from 30 to 60 KVA (load > 50 %)

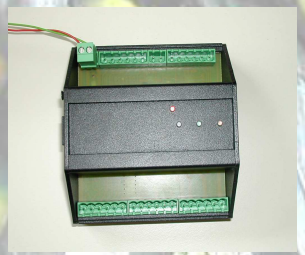
SYSTEM OF DOUBLE CIRCUIT or 2 TANKS SYSTEM

KIT for 2-TANK SYSTEM

Renault dci 270 Ch (2006)

Common Rail injection

SUNFLOWER OIL



SYSTEM OF DOUBLE CIRCUIT or 2 TANK SYSTEM

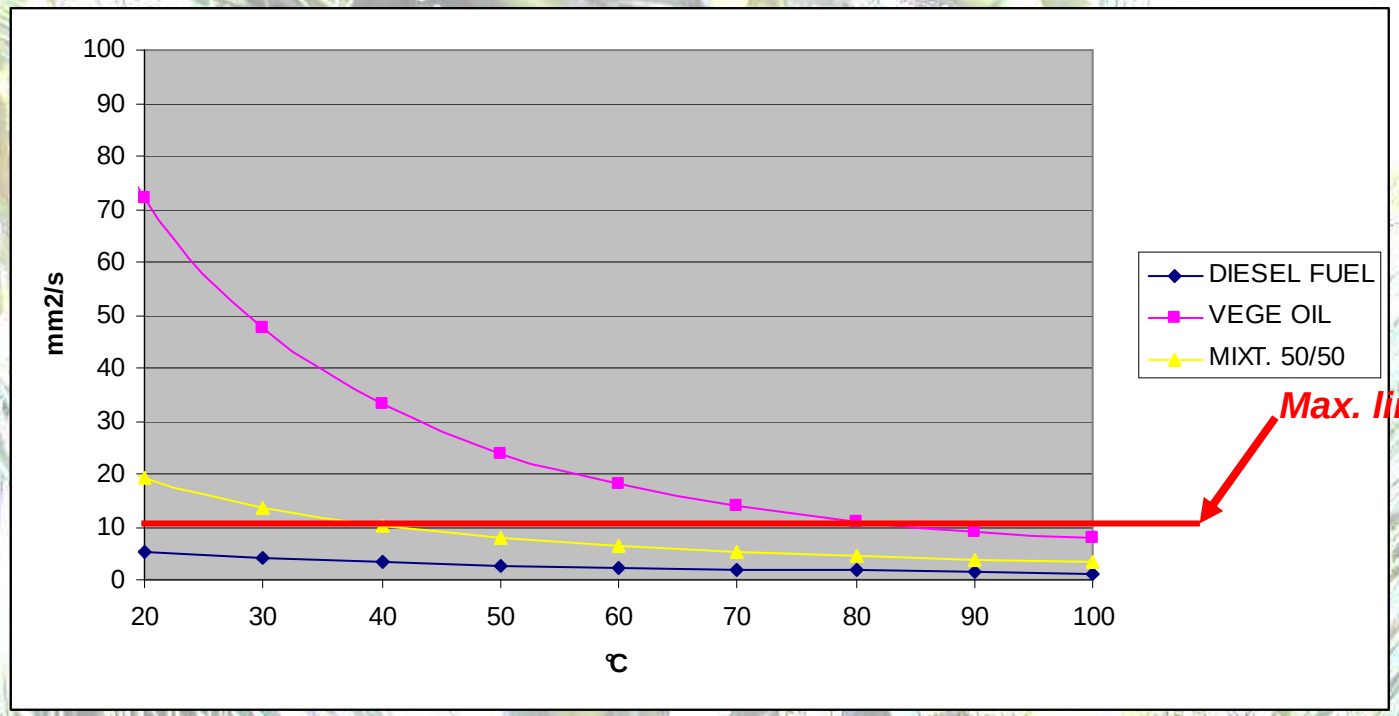
IVORY COAST

Genset 320 KVA – crude Palm Oil (2006)

MIXTURES OF COCONUT OIL
in STANDARD DIRECT INJECTION ENGINES

Filters, injectors, injection pumps, … have been designed for Diesel Fuel use (ref. 40℃). A too high viscosity m ay reduce flow and can damage injection pump.

MIXTURES ARE USEFUL ONLY TO REDUCE VISCOSITY



EXAMPLE OF MIXTURES OF COCONUT OIL in STANDARD DIRECT INJECTION ENGINES

BUT RUNNING ON 10 to 20 % CNO only WHEN LOAD > 50 % => > 200 KVA

Cummins genset , 400 KVA, 10-20 % CNO in DIESEL FUEL

Savai'i EPC Power station, Samoa (2005)

EXAMPLE OF MIXTURES OF COCONUT OIL in STANDARD DIRECT INJECTION ENGINES

BUT RUNNING ON 15 to 20 % CNO only WHEN LOAD > 50 %

Figure 21: UNELCO Generators in Port Vila running on coconut oil fuel blend *(Source: UNELCO)*

4MW MAN 9L32/40 generators on blends fuel/coconut oil
UNELCO Port Vila – 2006
Coconut oil is mixed or not to diesel fuel according to the load. (similar to a 2 tank-system)

Technology Updates

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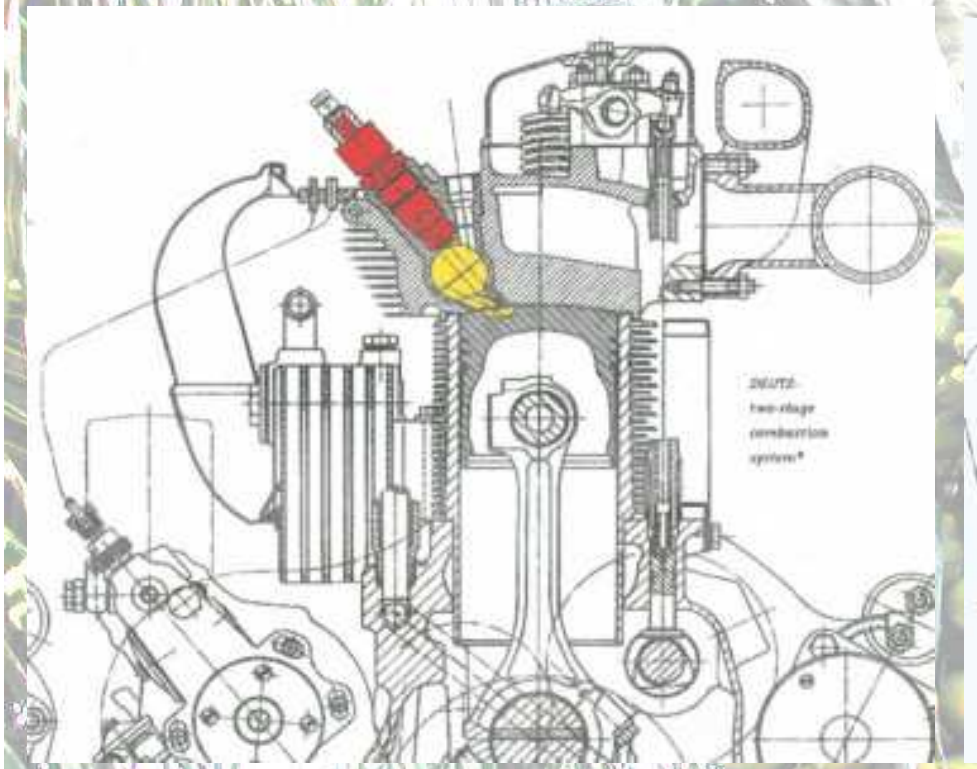
2. In specifically designed engines modified to burn vegetable oils at any percentage

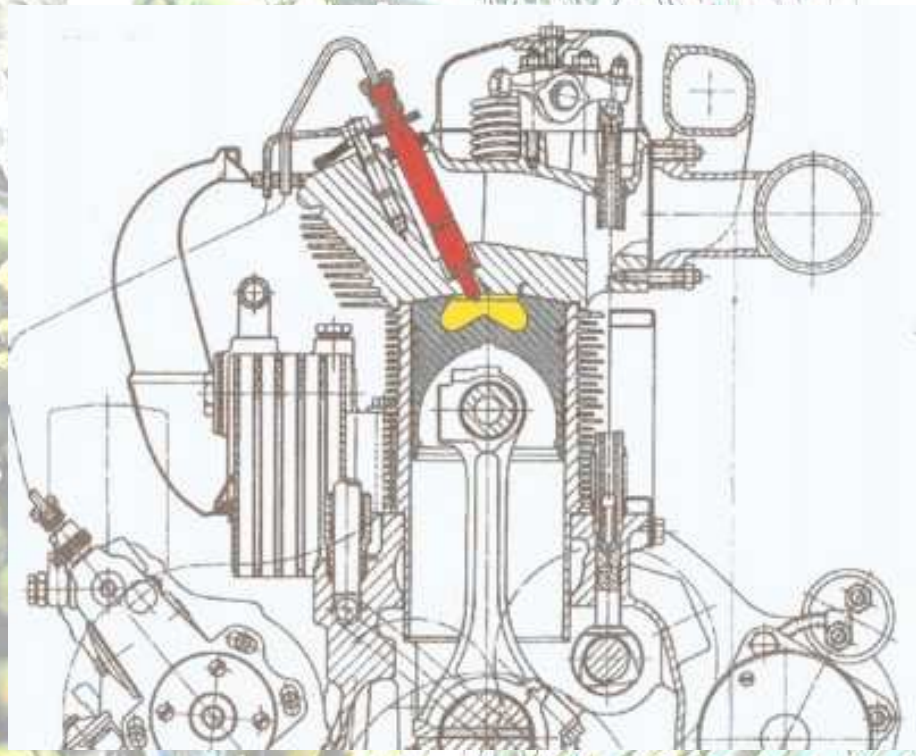
ARCHITECTURE OF DIESEL ENGINES

TWO TYPE OF DIESEL ENGINE

INDIRECT INJECTION



DIRECT INJECTION

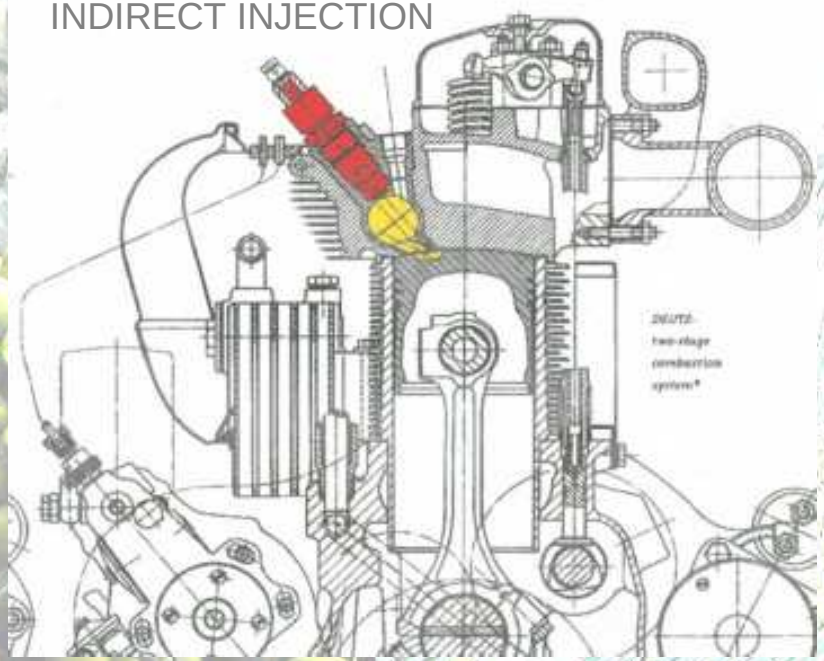


DEUTZ AIR COOLED ENGINES: 912, 914 AND 912W

PURE VEGETABLE OILS

INDIRECT INJECTION (IDI)

INDIRECT INJECTION



No modifications, only adaptation

Up to 100 % vegetable oil.

Heat exchanger and/or mixture with diesel fuel to reduce vegetable oil viscosity

& Some settings

DIESEL INDIRECT INJECTION

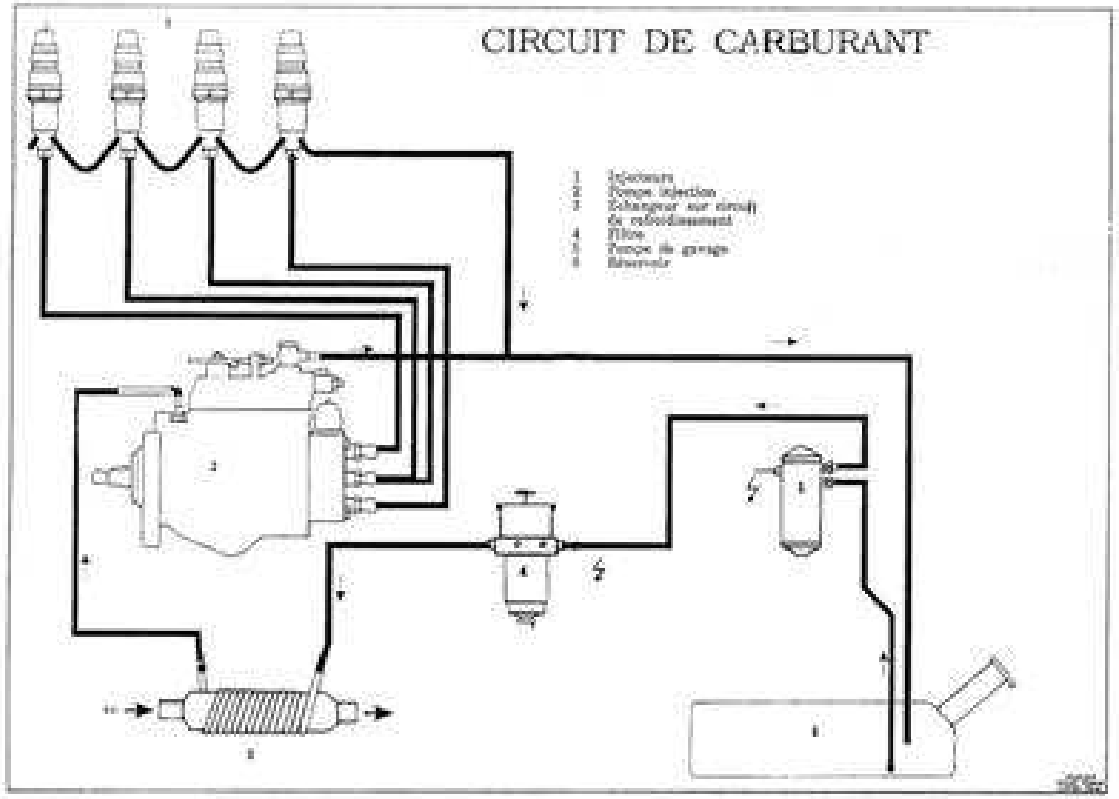
EXAMPLE

SETTINGS

- **injectors opening pressures: 200 bars**

Photo: Rabaul Hotel car

IDI coconut oil powered car in PNG. (Atul Raturi, 2006)



Technology Updates

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PURE VEGETABLE OILS

Modification of pistons

Example of combustion chamber

PURE VEGETABLE OILS

In specifically designed engines

DIESEL DIRECT INJECTION

In specifically designed engines

Tractor Biocombustible Yumz D-65 M, Sunflower or soja

UBPC Victoria 2, Camagüey – CUBA (2003)

In specifically designed engines

Tractor Yumz (Camagüey - Cuba)

Spare Piston

modified Piston

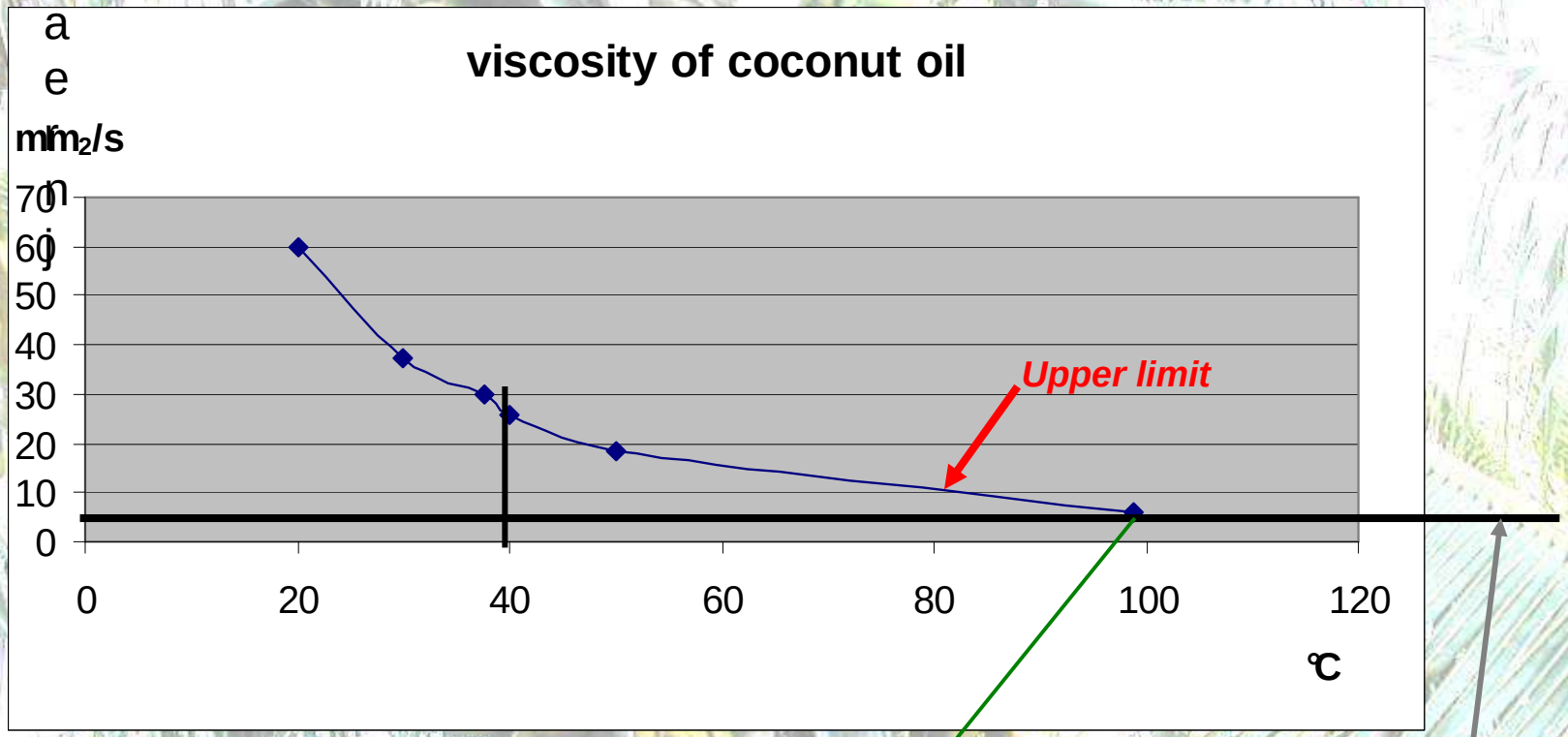
Filtered Crude Coconut Oil

Quality requirement as Biofuel for diesel engines

QUALITY OF COCONUT OIL BIOFUEL
1. reducing viscosity

Filters, injectors, injection pumps, … have been designed for Diesel Fuel use (ref. 40°C)

A too high viscosity may reduce flow and can damage pumps



Diesel fuel at 40°C

Coconut oil must be at 100°C

QUALITY OF COCONUT OIL BIOFUEL
2. Respecting a standard of quality

LTV-Work-Session on Decentral Vegetable Oil Production, Weihenstephan

Quality Standard for Rapeseed Oil as a Fuel (RK-Qualitätsstandard)

05/2000

in Cooperation with:

Properties / Contents	Unit	Limiting Value min.	Limiting Value max.	Testing Method
charcteristic properties for Rapeseed Oil				
Density (15 °C)	kg/m³	900	930	DIN EN ISO 3675 DIN EN ISO 12185
Flash Point by P.-M.	°C	220		DIN EN 22719
Calorific Value	kJ/kg	35000		DIN 51900-3
Kinematic Viscosity (40 °C)	mm²/s		38	DIN EN ISO 3104
Low Temperature Behaviour				Rotational Viscometer (testing conditions will be developed)
Cetane Number				Testing method will be reviewed
Carbon Residue	Mass-%		0.40	DIN EN ISO 10370
Iodine Number	g/100 g	100	120	DIN 53241-1
Sulphur Content	mg/kg		20	ASTM D5453-93
variable properties				
Contamination	mg/kg		25	DIN EN 12662
Acid Value	mg KOH/g		2.0	DIN EN ISO 660
Oxidation Stability (110 °C)	h	5.0		ISO 6886
Phosphorus Content	mg/kg		15	ASTM D3231-99
Ash Content	Mass-%		0.01	DIN EN ISO 6245
Water Content	Mass-%		0.075	pr EN ISO 12937

QUALITY OF COCONUT OIL BIOFUEL
Proposal of a quality standard

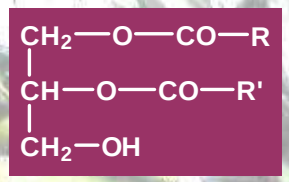
Quality standard for Coconut oil as fuel (proposal)				
Properties/content	Unit	Min.	Max.	Test method
Characteristic properties				
Density at 25℃	Kg/m^3	0,915	-	ASTM D1298
Flash Point	℃	210	-	ASTM D93
Calorific value	MJ/kg	37	-	
Viscosity (Kin. @ 40℃)	mm^2/s	-	30	ASTM D445
Carbon residue	Mass %	-	0,40	ASTM 4530
Sulphur content	mg/kg	-	20	ASTM D5453
Cetane Index		40	-	ASTM D4737
Variable properties				
Total contamination	mg/kg	-	25	ASTM 5452
Acid value	mg KOH/g	-	10	ISO 660
Oxidation stability (110℃)	h	4		ASTM D2274
Phosphorous content	mg/kg	-	15	ASTM D323
Ash content	Mass %	-	0,02	ISO 6245
Water content	Mass %	-	0,075	ISO 12937

Source: *G. Vaitilingom,J. Cloin. Pacific Regional Bioenergy Workshop 17 – 20 Nov. 2008 in Nadi, Fiji Islands*

QUALITY OF COCONUT OIL BIOFUEL
3. Taking chemical constraints in account

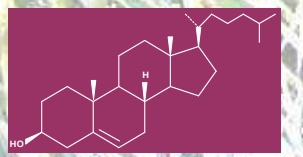
MINOR COMPONENTS: GUMS, WAXES,…

- **partial Glycerides**



- **Free Fatty Acids**

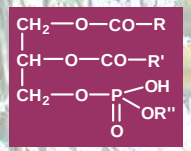
- **non-saponifiables, pigments…**



Sterols

tocopherols

- **Phosphatides**



➔ **Copra quality and process + filtration,…**

SENSITIVITY to COLD COND.

Begining of solidification

DIESEL	:	- 35 ℃
RAPESEED	:	- 11 ℃
Coconut Oil	:	+ 23 ℃

If Cno can solidify under local condition:

➔ **Start up and stop on diesel fuel (2 tank system,…)**

➔ **running on diesel fuel during cold weeks,…**

Environmental Impact

	Petrol	Diesel	Biodiesel Rapeseed	Biodiesel sunflower	Rapeseed oil pure	Sunflower Oil pure	Coconut Oil	Ethanol sugar cane	Ethanol wheat
Energy balance (Output / Input fossil)	0,879	0,913	3,3	3,44	5,09	5,78	15	7,34	3,57
Green House Gas indicator (g. equiv CO2/kg)	3560	3390	1332	1117	990	747	185	670	505

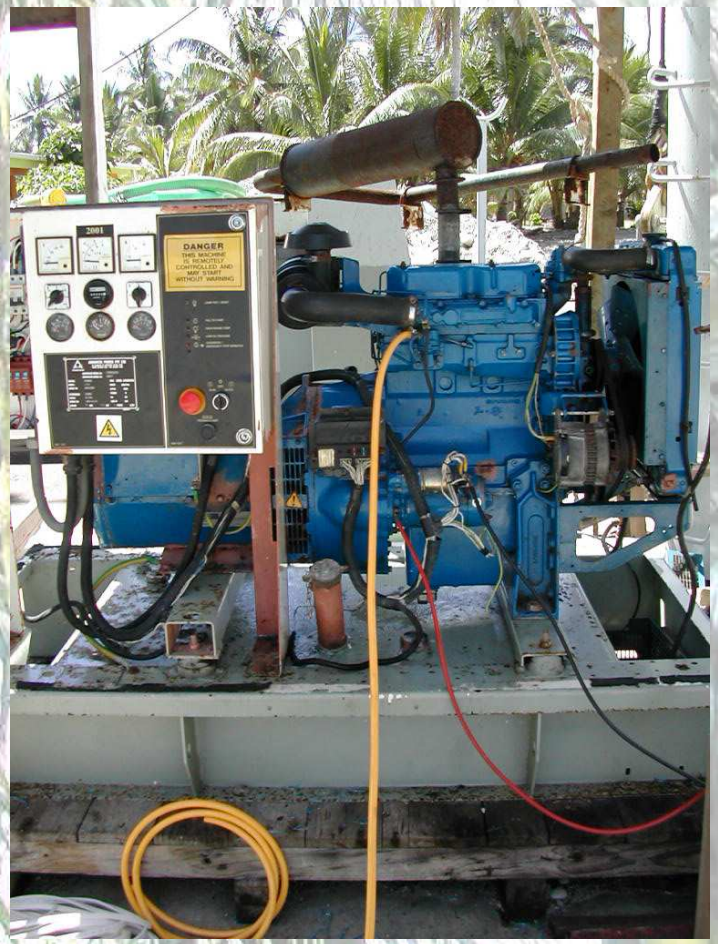
coconut plantations are assumed to use traditional, non-intensive farming practices with virtually no mechanization or utilization of chemical aids such as fertilizers and pesticides

Filtered Crude Coconut Oil

In the Pacific:

examples

CRUDE FILTERED COCONUT OIL ESTERIFIED WITH METHANOL ➔ BIODIESEL



GENSET 30 KVA.

TUVALU, 2009;

MIXTURES OF FCCNO with DIESEL FUEL IN STANDARD DIRECT INJECTION ENGINES

BUT RUNNING ON CNO only WHEN LOAD > 50 %

4MW MAN 9L32/40 generators on blends fuel/coconut oil
UNELCO Port Vila - 2004

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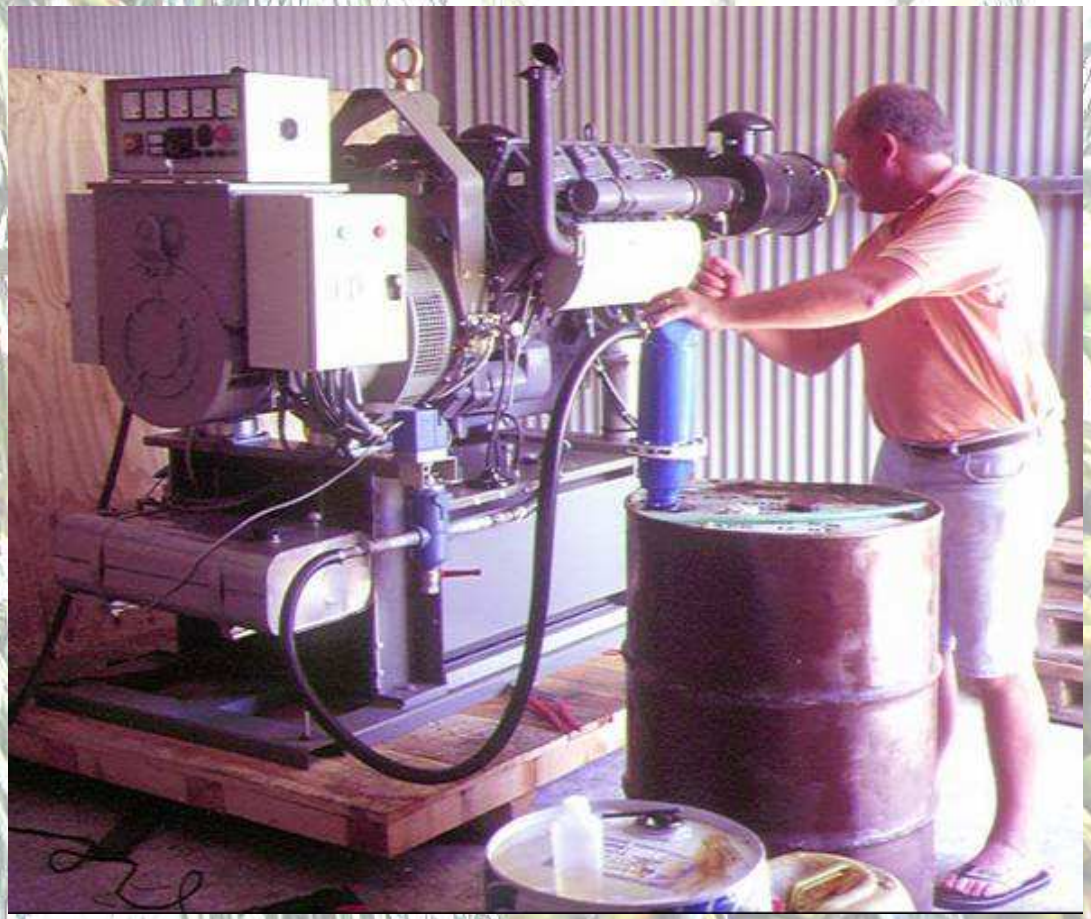
CRUDE FILTERED COCONUT OIL
IN IDI DIESEL ENGINE

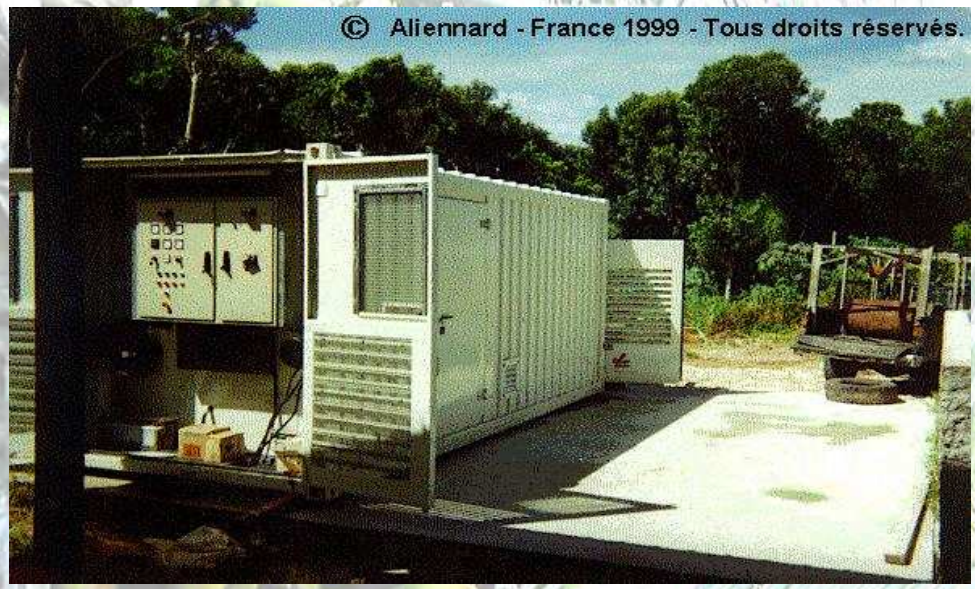


COMMUNE D'OUVEA

1995, first Ouvea GENSET. 90KVA

New Caledonia

CRUDE FILTERED COCONUT OIL
IN IDI DIESEL ENGINE



1999, GENSET 200KVA

DESALINATION PLANT, OUVEA-NEW CALEDONIA

FILTERED CRUDE COCONUT OIL AS FUEL

IDI ADAPTED ENGINES + DUAL FUEL SYSTEM

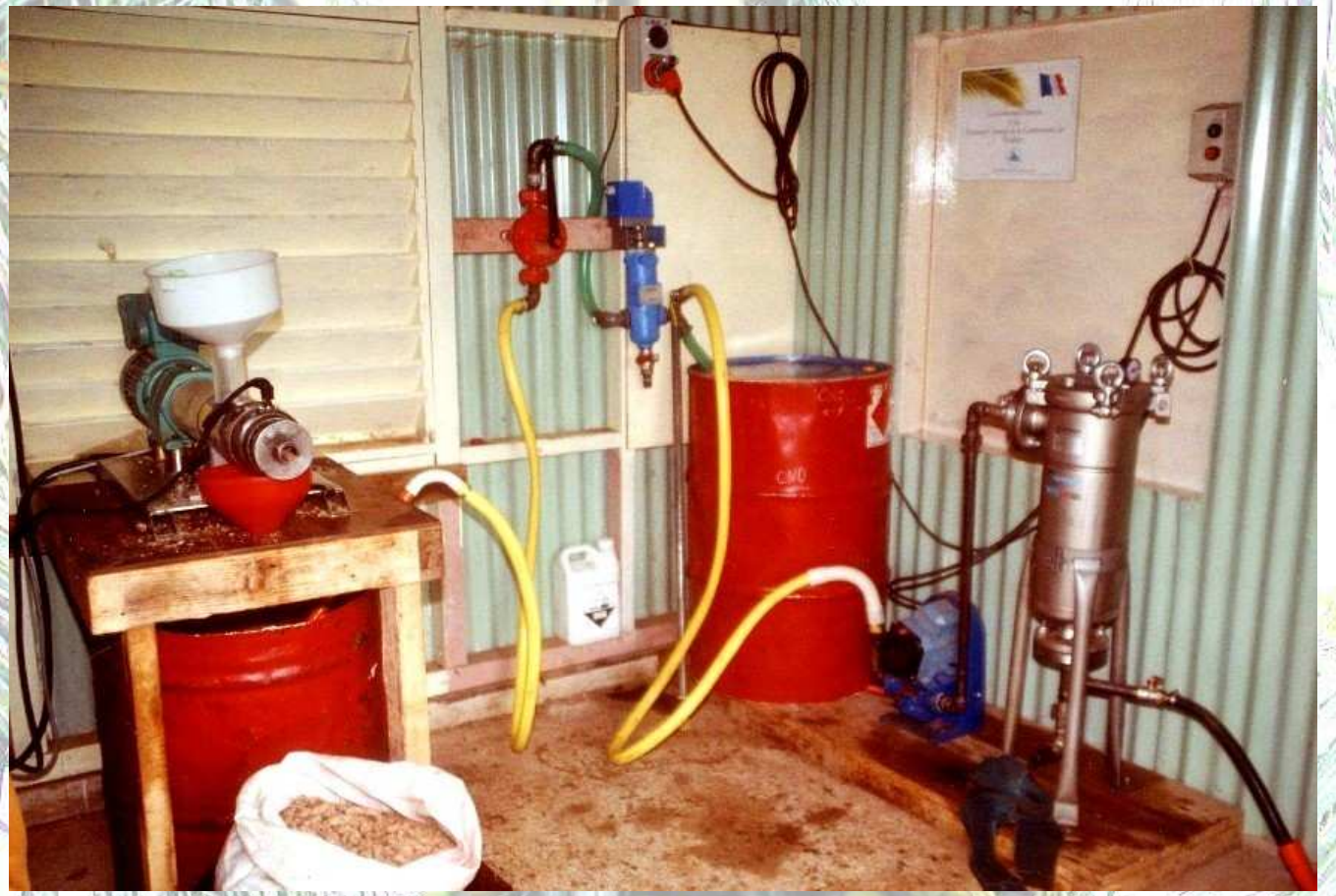
RURAL ELECTRIFICATION:

Fiji: Vanuabalavu 80 KVA* (2000) & Welagi 45 KVA (2001)

Coconut Oil as fuel (10 nuts = 1 litre equivalent Diesel Fuel)

** First place in the World to produce grid electricity with its own vegetable oil (April 2000).*

PURE VEGETABLE OILS AT SMALL SCALE LEVEL



The pre-filtered coconut oil (drum on the left) is pumped by an electrical driven-pump (between drum and filter) and pushed through a flow line bag-filter (on the right).
The hose at the bottom right is connected to the coconut oil main tank of the generator.

CRUDE FILTERED COCONUT OIL

In specifically designed engines

2004 GENSET. 300KVA

Power Station of ENERCAL (Utility)

CRUDE COCONUT OIL IN MODIFIED DIESEL ENGINE

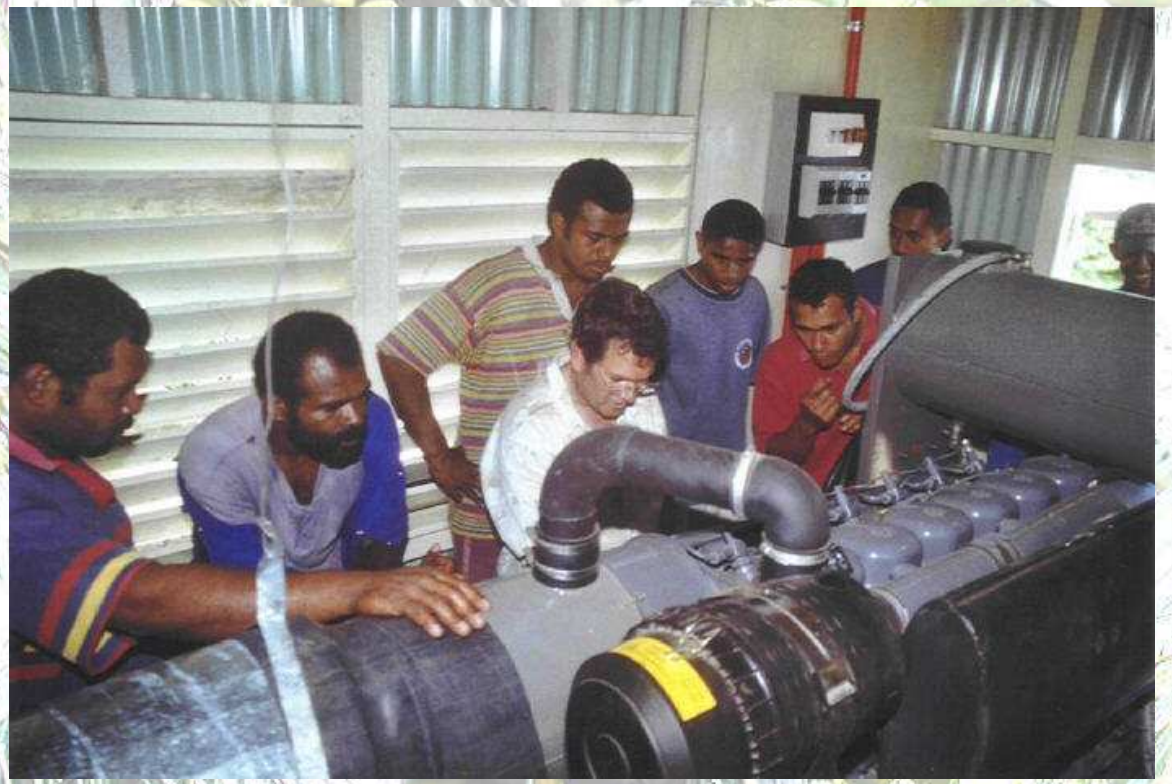
2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)

CRUDE COCONUT OIL IN MODIFIED DIESEL ENGINE

2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)

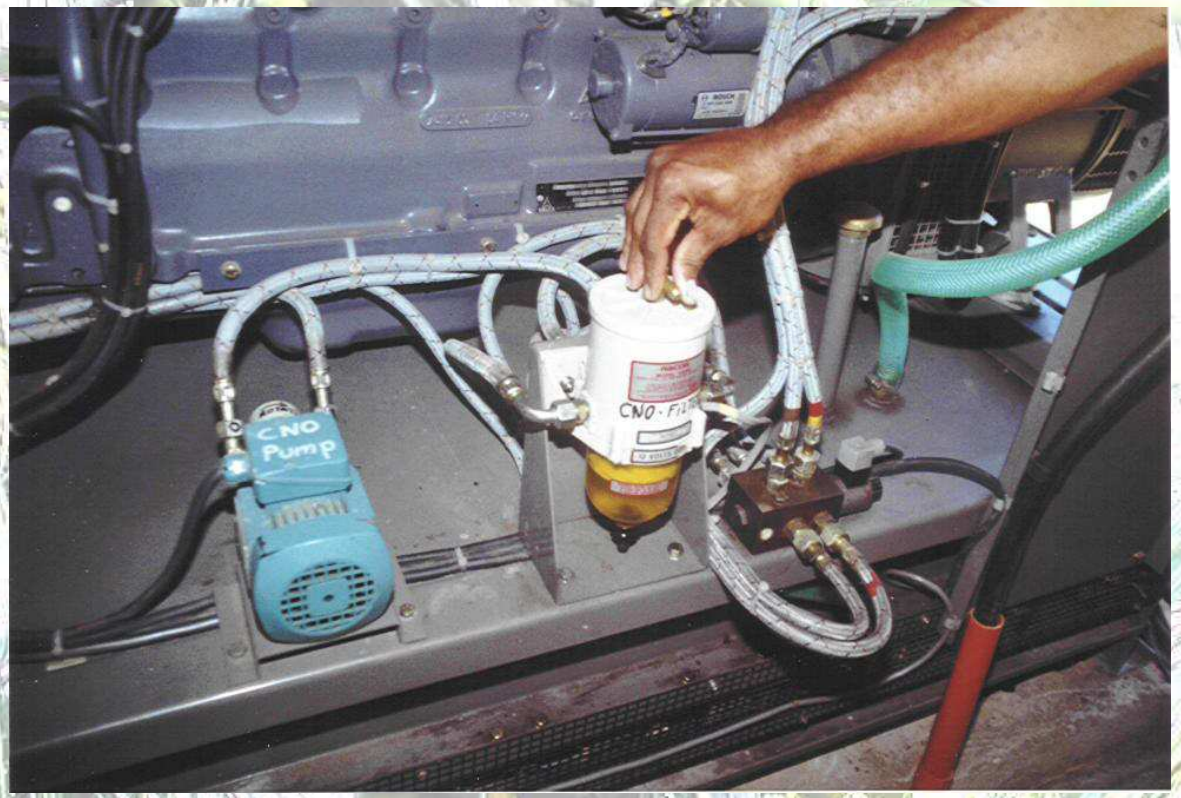
COCONUT OIL FOR ELECTRICITY GENERATION

GOOD TRAINING



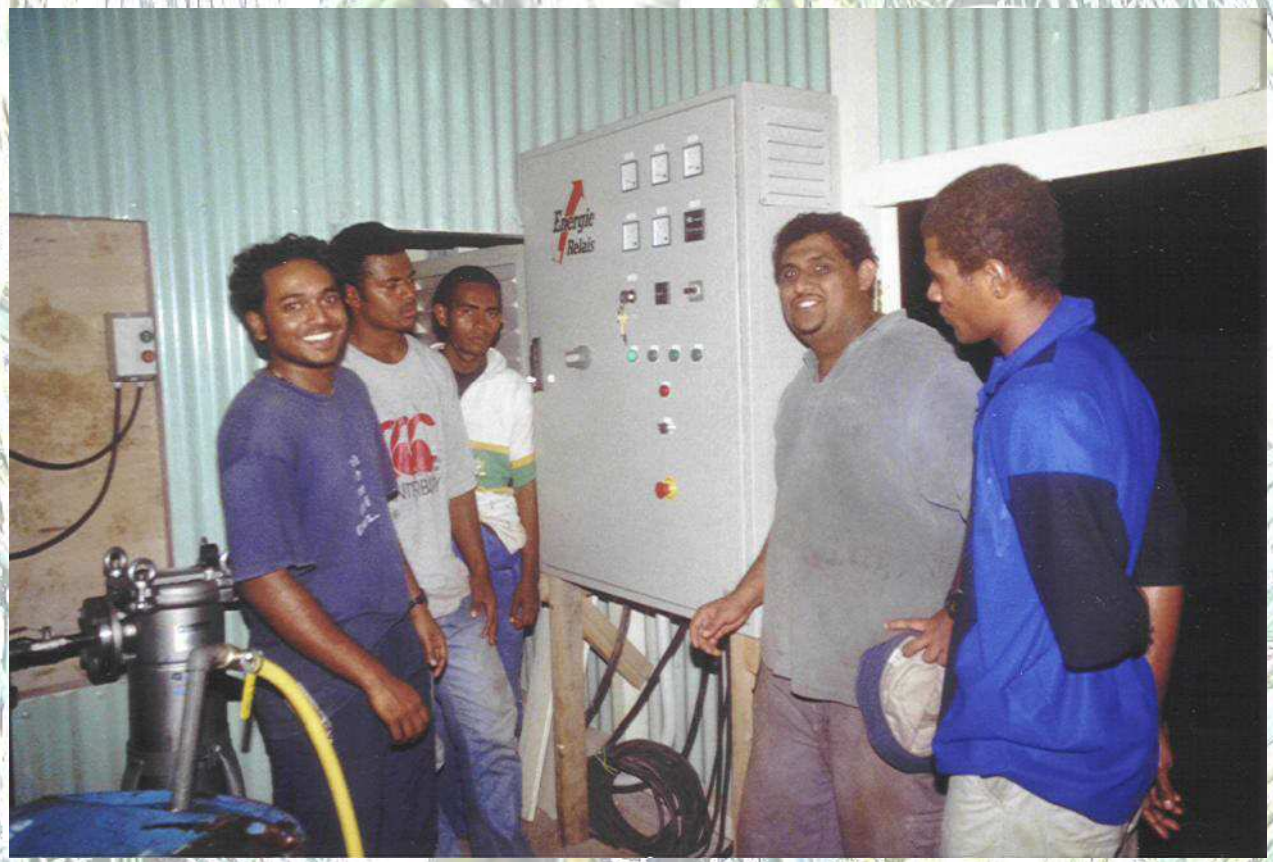
COCONUT OIL FOR ELECTRICITY GENERATION

AND GOOD MAINTENANCE



COCONUT OIL FOR ELECTRICITY GENERATION

MAKE PEOPLE HAPPY !



DoE staff at the very starting of Welagi genset with coconut oil (July 2001)

Vinaka!

ETHANOL BIOFUEL FROM TODDY

Example of BioEthanol production

Ethanol produced from todi. TUVALU

1 TREE CAN PRODUCE UP TO 25 LITERS OF TODDY/DAY

Or from 2 to 2.5 LITERS OF ETHANOL BIOFUEL / DAY